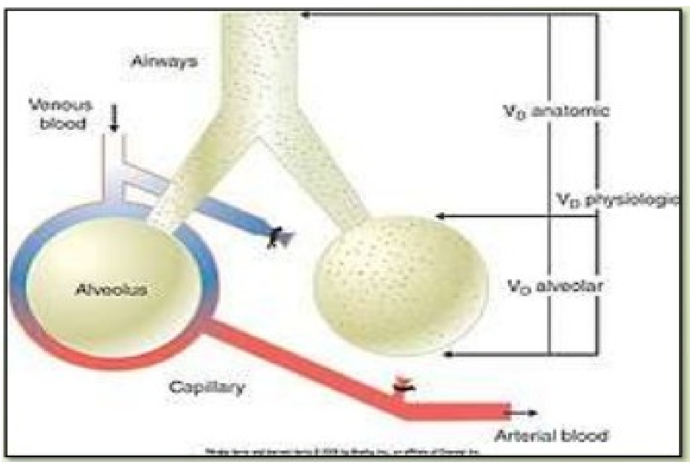
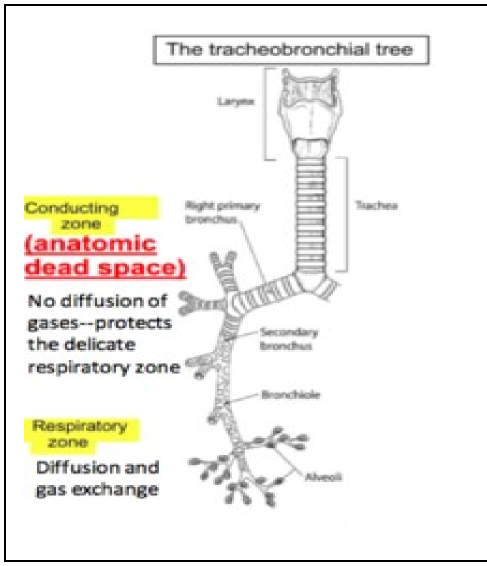
The Dead

Definition:

Dead space is the volume of air in the respiratory system which does not take a part in gas exchange with blood. so regions of the respiratory system that contain air but are not exchanging O_2 and CO_2 with blood are considered dead space.



Anatomical, physiological dead spaces



Types:

1. **Anatomical dead space:** it is the volume of air in the conducting airways which ends at the level of terminal bronchioles (nasal cavity, pharynx, trachea, bronchi, terminal bronchioles), where no gas exchange takes place. (because of the inherent structure of these airways, they are not capable of O_2 and CO_2 exchange with the blood so considered as dead space). it is about **150 ml**.

✓ It is <u>increased</u> with:
- Upright posture.
- Inspiration.
- Bronchodilation.
- Anesthesia.
- Drugs e.g B2 agonists and cholinergic drugs.
- Increasing breathing rate.

✓ It is <u>decreased</u> with:
- Supine posture.
- Bronchoconstriction.
- Endotracheal intubation.
- Hypoxia.
- Histamine.

2. **Alveolar dead space:** it is the volume of air within non perfused alveoli and thus not participating in gas exchange. i.e alveoli containing air but without blood flow in the surrounding capillaries are considered alveolar dead space. An example is a pulmonary embolus.

- In healthy people, alveolar dead space is very small and is usually negligible, but it can increase to even lethal levels in pulmonary diseases.
- Alveolar DS is <u>increased</u> by presence of poorly perfused alveoli e.g decreased pulmonary blood flow.
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3. **Physiological (total) dead space:** it refers to the total dead space in the lung system

Physiological DS = Anatomical dead space + Alveolar dead space

- So, under normal conditions physiological dead space and anatomical dead space are nearly equal, because all alveoli are functioning in normal lung.
- When the physiological DS is greater than the anatomical DS, it implies the presence of alveolar DS, i.e., somewhere in the lung, alveoli are being ventilated but not perfused.
- However, under pathological conditions, physiological dead space is more than anatomical dead space.
- Physiological DS <u>increased</u> by
    - ↑ in alveolar DS e.g non perfused alveoli e.g ↓ pulmonary blood flow
    - ↑ in anatomical DS e.g ↑ breathing rate.

<u>Significance of the dead space:</u>

1. It is responsible for the difference between pulmonary ventilation (minute respiratory volume) and alveolar ventilation.

✓ Minute ventilation is the total volume of air entering the lungs per minute. i.e it is the volume of air inspired or expired per minute at rest.

- It equals the tidal volume times the respiratory rate
- Pulmonary (minute) ventilation = Tidal volume X respiratory rate

e.g Pulmonary ventilation = 500X 12= 6000 ml/min.

- ✓ While alveolar ventilation is volume of air enters in gas exchange per minute during rest. It represents the room air delivered to the respiratory zone per breath.
- ✓ The first 150 mL of each inspiration comes from the anatomic dead space and does not contribute to alveolar ventilation. However, every additional mL beyond 150 does contribute to alveolar ventilation.
  - Alveolar ventilation = (Tidal volume – Dead space) X respiratory rate

= (500 mL – 150 mL) x12 = 4200 ml/min

2. Because of the dead space, rapid shallow breathing produces much less alveolar ventilation than slow deep breathing at the same respiratory minute volume air.

- The importance of calculating the alveolar ventilation is evident in conditions of shallow rapid breathing. In these conditions, the tidal volume is decreased while the respiratory rate is increased. Rapid breathing increases wasted air in the dead space. therefore, pulmonary ventilation may be normal, while the alveolar ventilation become markedly decreased.
- In this example, Person A has rapid, shallow breathing. Although in this person pulmonary ventilation (minute volume) may be normal (6L), alveolar ventilation is decreased (1500 ml). Therefore, the individual is hypoventilating.

	Person A	**Person B**
Respiratory rate	30 /min	10 /min
Tidal volume	200 ml	600 ml

Pulmonary ventilation	6 L	6 L
Alveolar ventilation	(200 -150) X 30 =1500 ml	(600 -150) x10 = 4500 ml

3. It is responsible for the difference between composition of alveolar air and expired air.

- Expired air is a mixture of dead space (fresh atmospheric air) and alveolar (old air). therefore, expired air contains higher PO_2 and less PCO_2 than alveolar air.

4. Humidification & warming inspired air before reaching alveoli.
5. Protection of alveoli from damage by foreign particles & bacteria (e.g filtration function of nose, mucous, sneezing& coughing reflexes).
6. Phonation (production of sounds by vibration of vocal cords in larynx by expired air).
7. Smell sensation as the nose contains olfactory receptors.
8. It is one of pulmonary function tests.

During inspiration:

- Not all the inspired air (atmospheric) (tidal volume) (500 ml) get down to the site of gas exchange in the alveoli. Part of it remains in the conducting airways, where it is not available for gas exchange
- The volume of air occupying the conducting airways is called anatomic dead space & averages 150 ml and the remaining volume of air enters the alveoli = Tidal volume – dead space volume

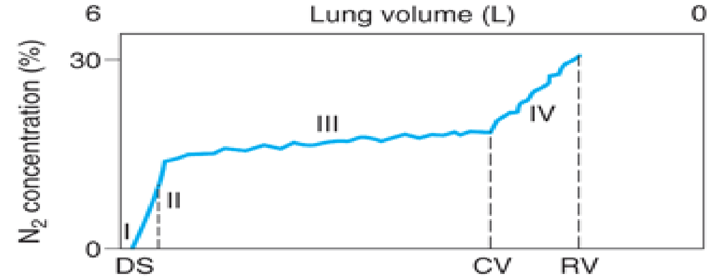
  = (500-150) = 350 ml
- At the end of inspiration, DS contains atmospheric air (fresh air)

During expiration:

Measurement of dead space:

I. Single breath nitrogen test (Fowler method):

1. The subject takes as deep a breath of pure O_2.
2. He exhales steadily through a nitrogen meter so the N_2 content of the expired air is continuously measured.
3. The initial air exhaled (phase I) is the air that filled the dead space & contains no N_2. This is followed by a mixture of dead space & alveolar air (phase II) and then by alveolar air (phase III).
4. The volume of the dead space = phase I + mid portion of phase II.



Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com

II. By Bohr's Equation:

- The Physiological dead space is measured by this technique depending on the fact that the CO_2 content

CO2% in alveolar air - CO2% in expired air

Dead space volume = Tidal volume X

of expired air is derived entirely from the alveolar air.

- For example, If CO_2% in expired air is 0.04 %, CO_2% in alveolar air is 0.06 % and tidal volume is 500 ml, so the volume of dead space= 500 x (0.06-0.04)/ 0.06 = 165 ml

- Since the partial pressure (P) of a gas is proportionate to its concentration, so PCO_2 can be used instead of CO% in this equation to calculate the volume of dead space.